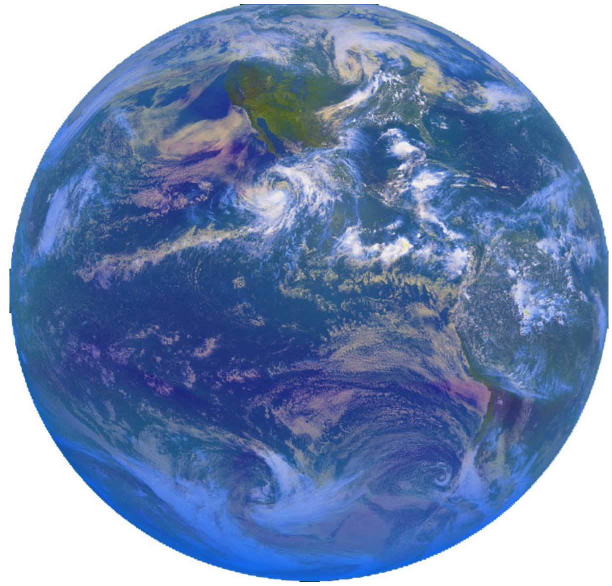
El Niño and La Niña

Problem: *What is the relationship between sea temperature, wind direction, and convection along the equatorial Pacific during an El Niño event and a La Niña event?*

Materials: *Colored pencils*



Background

The children of the tropics, El Niño and La Niña sometimes cause chaos even when they are behaving as they should. El Niño is a term used to describe a change in the ocean-atmosphere system of the tropical Pacific Ocean that affects weather around the globe!

Originally named by fishermen along the coasts of Ecuador and Peru, the Spanish term El Niño for "the Christ Child," refers to the warm ocean current that usually appears around Christmas-time and lasts for several months. In the past 30 years, scientists have found that the appearance of this warm current is related to an unusual warming of the whole tropical Pacific Ocean. Now, this basin wide warming is also referred to as El Niño. Refer to Figure 5.1.

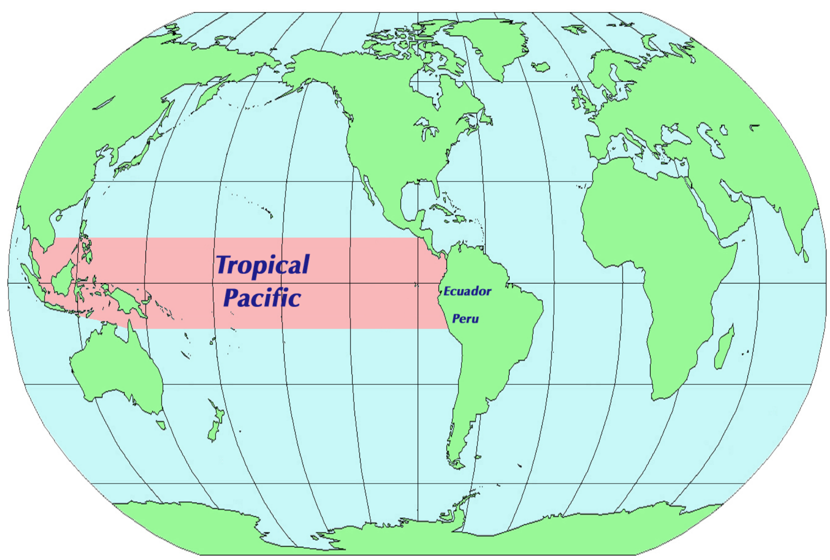


Figure 5.1. Tropical Pacific Ocean Basin

In contrast, La Niña means "the Little Girl" in Spanish and refers to the unusually cold ocean temperatures in the Pacific near the equator. Normal conditions vary in-between these two extremes.

Under normal ocean-atmosphere conditions, winds in the Pacific blow from east to west across the tropical Pacific Ocean. These winds cause the water in the west Pacific to pile up so that the water surface at Indonesia is about ½ meter higher than at Ecuador! At the same time, the sea surface temperature is about 8 °C warmer in the west because it is the warm surface water, heated by the sun, that has been blown from east to west. As the warm surface water moves westward, cool water emerges from below to take its place.

Warm ocean water has a significant impact on the atmosphere above it. Over very warm ocean water, evaporation increases, surface winds converge, clouds form, thunderstorm activity increases, and heavy rain can occur. It's like turning up the stove and bringing a pot of water to a slow, simmering boil - warm water rises and the bubbles burst forth. The water that rises in the pot is replaced by warm water flowing in from all sides. This process of transferring heat is called convection. In the atmosphere, thunderstorms form instead of bubbles.

Convection is a key element in the ocean-atmosphere system because it forms the link between winds and sea surface temperature. In general, convection occurs over the warmest water and winds blow into the region from all directions.

El Niño

During El Niño conditions, large-scale winds that normally blow from east to west across the Pacific Ocean slacken, and sometimes even reverse direction. When this happens, the warm water in the western Pacific sloshes back across the Pacific toward South America. The convection process shifts with the warm water so the clouds and storms move to the central Pacific.

In addition to causing a change in the atmosphere, this surge of warm water to the east prevents the deep cold water nutrients from rising in the ocean because there is a deeper layer of warm water on the surface. The result is less food for the tiny phytoplankton that feed on the rising nutrients and less food for all the creatures at higher levels of the marine (sea) food web.

What are the effects of El Niño? Whether you interpret the effects of El Niño as good or bad depends largely upon where you live. For example, the 1997 El Niño included record flooding in Chile, an extensive drought in Indonesia, heavy rains over the southern part of the U.S. including record rains in California and Florida, and an unusually mild winter in the U.S. Midwest. In Peru, the plentiful fish supply dwindled, but increased in Chile as some sea creatures moved south into colder water.

La Niña

During La Niña, ocean-atmosphere conditions evident during El Niño reverse. The eastern Pacific is cooler than usual and the cool water extends farther westward than usual. A La Niña often follows directly after an El Niño event. Together El Niño and La Niña are known as the El Niño–Southern Oscillation (ENSO) cycle with El Niño being the warm phase and La Niña being the cold phase of the ENSO cycle.

Generally, the global climate effects of La Niña tend to be opposite those of El Niño. At higher latitudes, the impact of both El Niño and La Niña can be most clearly seen during the winter. In the continental U.S., temperatures in the winter are warmer than normal in the southeast, and cooler than normal in the north-west. In Peru, the fish supply becomes plentiful.

Peru is one country already successfully using El Niño and La Niña predictions for agricultural planning. Because they suffer a disproportionate share of the consequences from the weather extremes caused by El Niño, tropical countries have the most to gain from successful predictions. However, countries outside the tropics, such as Japan and the U.S. also will benefit from planning in areas such as agriculture, water resources, fisheries, and reserves of grain and fuel; and, therefore, can better prepare for emergencies such as droughts, floods, and other extreme weather.

FYI

Predicting El Niño

The El Niño phenomenon repeats itself about every 3 - 7 years. While this is useful information for researchers, it does not make for very easy predictions of specific El Niño events. This is quite unlike other phenomena in the **ocean - atmosphere system**. For example, with the seasonal cycle, we can predict that temperatures will be colder during winter and warmer during summer. Similarly, for the diurnal (daily) cycle, we predict that temperatures will be warm during the day and cool at night. The latter are referred to as oscillating or periodic (repeating) phenomena. El Niño, however, is not periodic and shows considerable irregular behavior. Since the **ocean - atmosphere** models used to forecast El Niño have had only modest success, we need more research to improve forecasts.

Procedure

The data for this activity were collected from the Tropical Atmosphere Ocean Project (TAO) array of approximately 70 moored TAO and TRITON buoys in the equatorial Pacific that monitor changes in Pacific Ocean temperatures, currents, and surface weather conditions. The small squares in Figure 5.2 show where the buoys are located.

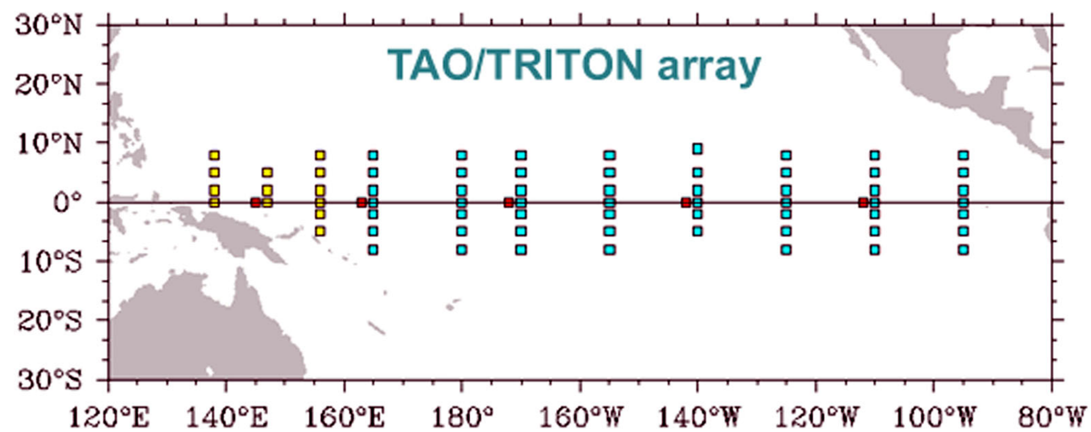


Figure 5.2. TAO/TRITON Buoy Array

TAO buoys are located in the eastern and central Pacific, while Japanese TRITON buoys are located in the western Pacific.

To better understand ocean temperature patterns and then changes, researchers use a map consisting of isotherms. An isotherm is a line connecting locations that have equal temperatures. Making an isotherm map is like doing a "dot to dot" puzzle except that isotherm lines should not intersect.

The following procedure will help you to make a map that shows how temperature changes with ocean depth in the tropical Pacific near the equator.

1. On Figure 5.3, find and draw the isotherm where the ocean temperature equals 26° C. Use the steps as follows:

   a. Find pairs of numbers in each column for which one number is greater and one number is less than 26. For example, in the column near 147°E longitude, the temperature is 27.3°C at 50 m depth and 25.1°C at 75 m. Therefore, the 26°C isotherm is between 50 m and 75 m. The isotherm is slightly closer to 75 m since 26 is closer to 25.1 than to 27.3.

   b. To help you get started, the 26° C isotherm has been drawn on Figure 5.3 between 140°E and 180°. Continue it across the Pacific Ocean to 95°W.

   c. Repeat the process for the 23°C, 20°C, 17°C, 14°C, 11°C, and 9°C.

2. Using colored pencils and the key provided, color the spaces between the isotherms.

3. Repeat the same procedure using Figure 5.4.

Color Key °C

>26	=	Red
23 - 26	=	Orange
20 - 23	=	Yellow
17 - 20	=	Light Green
14 - 17	=	Dark Green
11 - 14	=	Light Blue
09 - 11	=	Dark Blue
<9	=	Violet

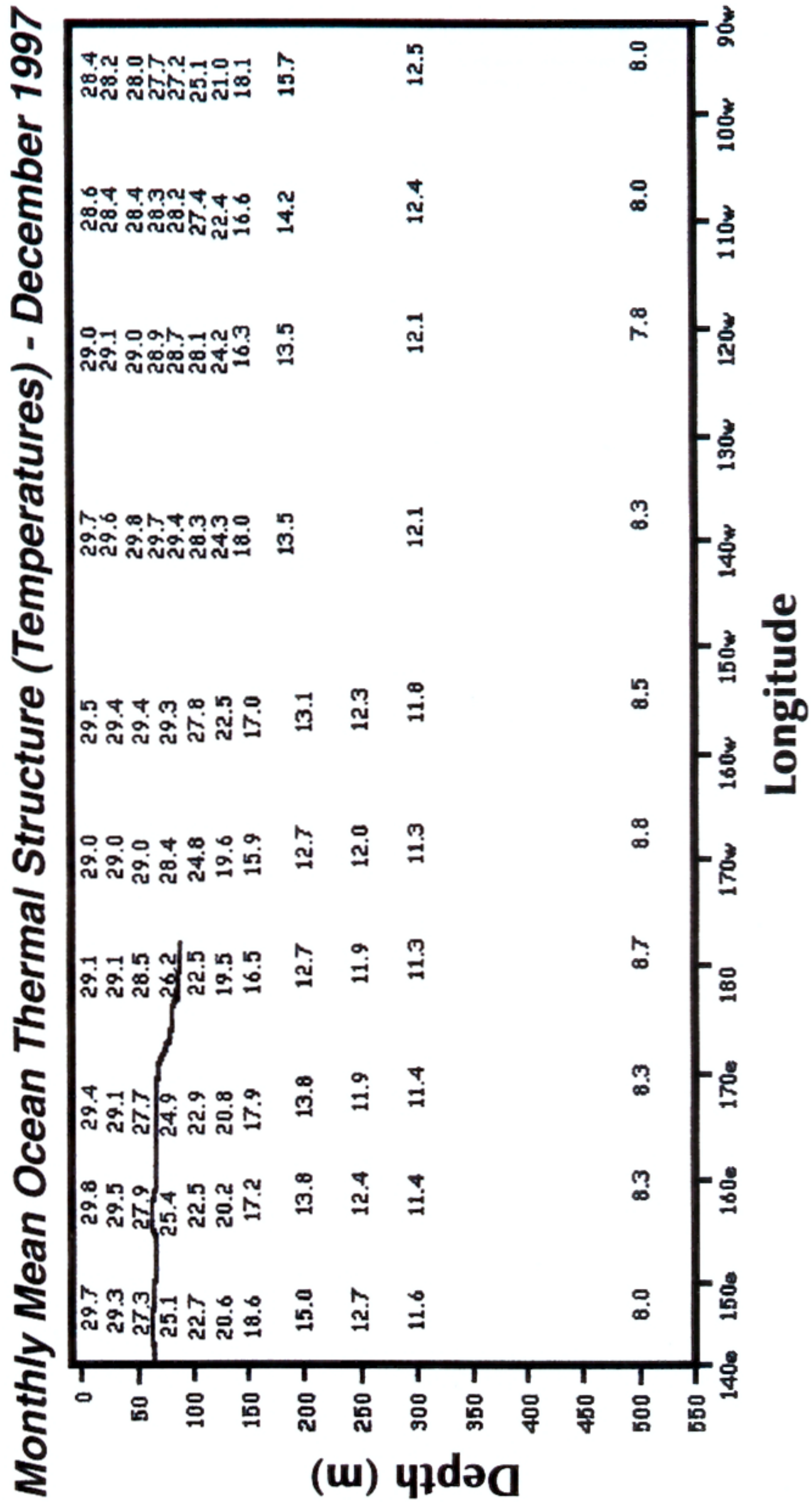


Figure 5.3. Ocean Thermal Structure Map - December 1997

5-5

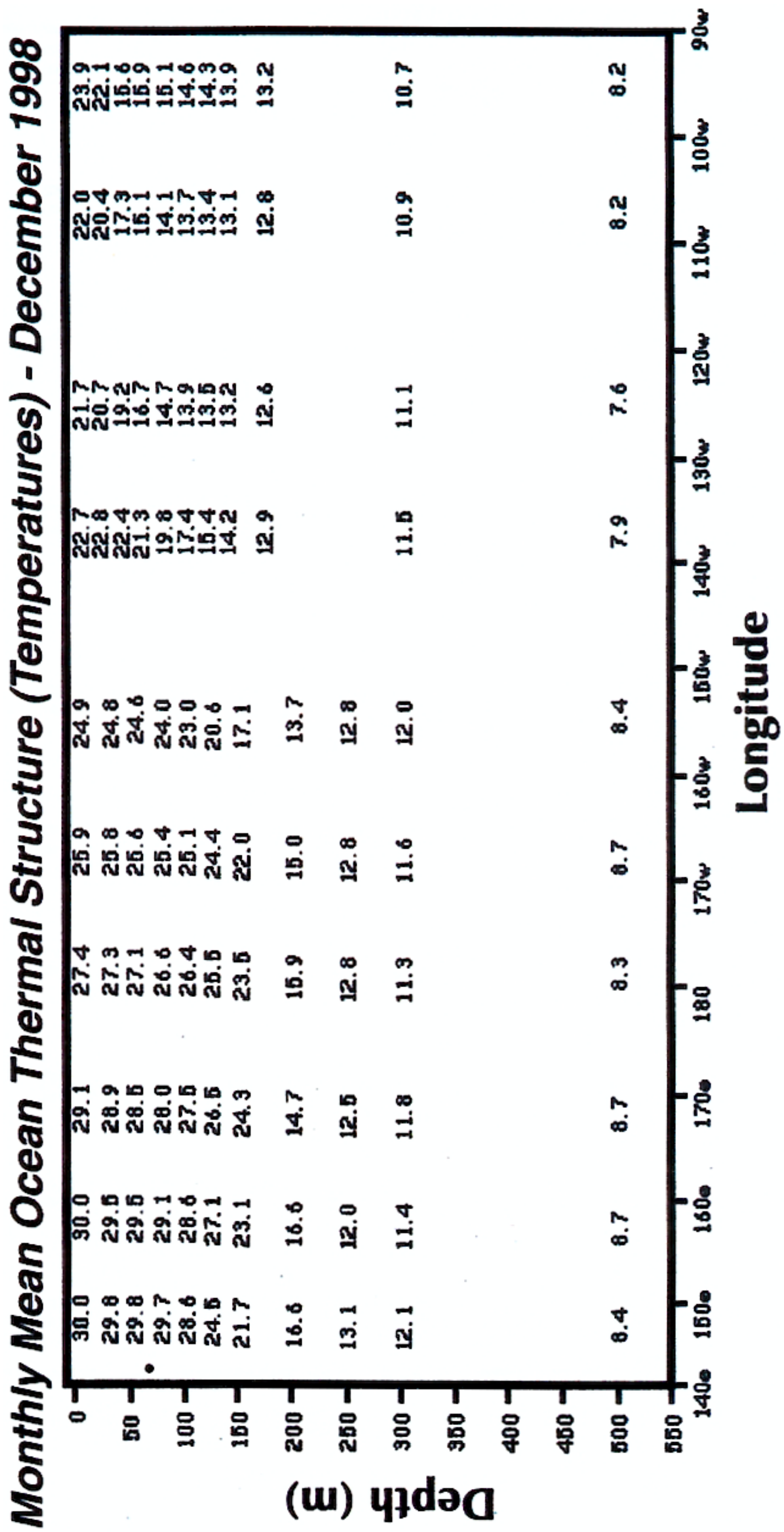


Figure 5.4. Ocean Thermal Structure Map - December 1998

Questions

1. On Figure 5.3, at what longitude(s) is the warm water (> 26°C) the deepest?

2. On Figure 5.4, at what longitude(s) is the warm water (> 26°C) the deepest?

3. Explain how you might tell what direction the wind is coming from based on the warmest sea surface temperatures.

4. On Figure 5.4, from which direction must the wind be blowing?

5. Which figure (Figure 5.3 or Figure 5.4) shows an El Niño event? How can you tell?

6. Which figure (Figure 5.3 or Figure 5.4) shows an La Niña event? How can you tell?

7. On Figure 5.3, at what longitude(s) and near what continent(s) would you expect convection, and therefore, severe storms?

Explain.

8. On Figure 5.4, at what longitude(s) and near what continent(s) would you expect good fishing?

Explain.

9. On Figure 5.3, at what longitude(s) and over what part of the Pacific Ocean (north, south, east, or west) would you expect drought?

Explain.

10. The last El Niño occurred in 1997 - 1998. If El Niño was a periodic phenomenon with a period of four years, when would the next El Niño occur?

11. Explain the similarities between the El Niño and the La Niña phenomenon.

12. A thermocline is a layer of water across which temperature changes rapidly with height. Explain how the slope of the thermocline changes between El Niño and La Niña conditions. (Hint: Look at areas where isotherms are close together.)

13. Many pieces of the El Niño - La Niña puzzle remain missing. What are some questions that might be answered through scientific investigation?

Conclusion

Review the problem stated on the first page and write a detailed conclusion. Include a diagram as part of your explanation.

Supplimental Information

Besides the subsurface ocean temperatures, currents, and surface weather conditions, the TAO/TRITON Buoy Array also provides sea surface temperature (SST) data. This is another important scientific data parameter used to help analyze and understand the El Niño and La Niña phenomena. Figure 5.5 and Figure 5.6 show maps of SST monthly averages and monthly anomalies, plus average winds and wind anomalies, from 10°N to 10°S, across the entire tropical Pacific basin. Figure 5.5 is from the mature phase of an El Niño event, while Figure 5.6 is from the mature phase of a La Niña event.

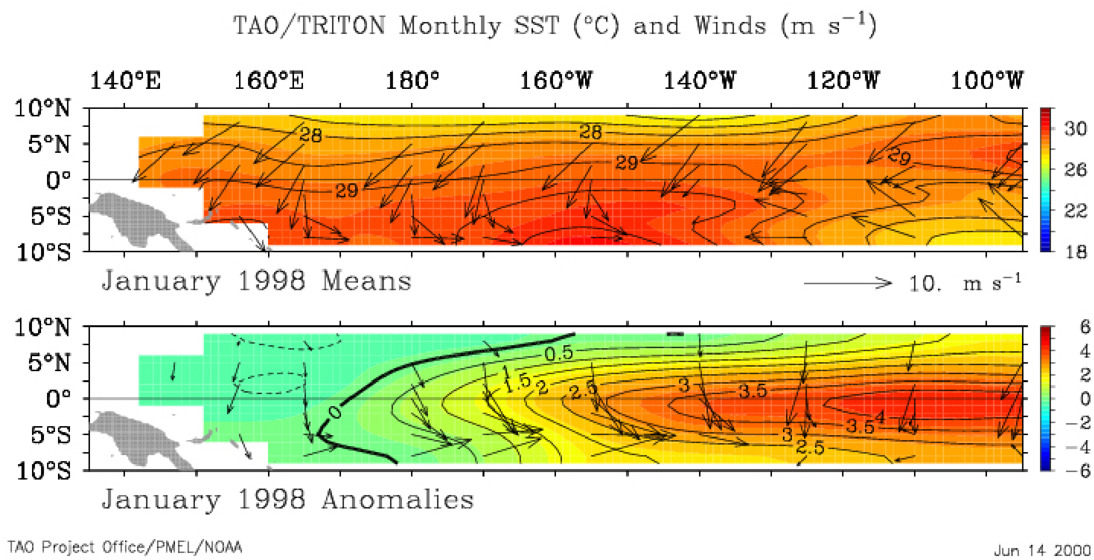


Figure 5.5. Sea Surface Temperature and Winds - January 1998 - El Niño Event

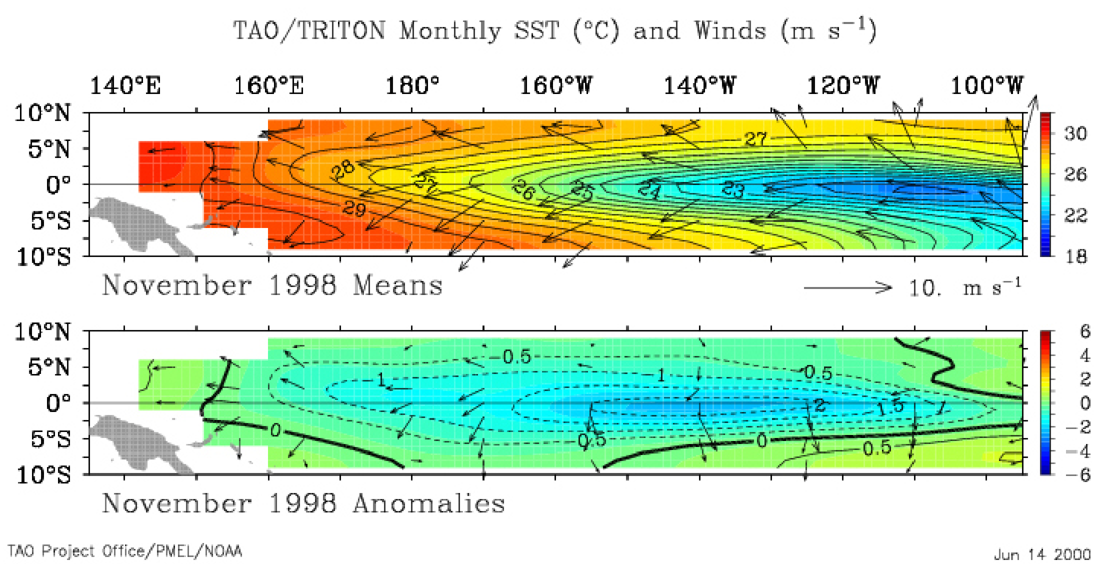


Figure 5.6. Sea Surface Temperature and Winds - November 1998 - La Niña Event

As an extra question you can think about and answer...

1. What are the differences in the structure of the sea surface temperature for the tropical Pacific Ocean basin between an El Niño event and a La Niña event?

For extra research...

1. What causes these differences?